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POSSIBILITY OF DEVELOPMENT OF SEMICONDUCTOR INDUSTRY
IN UNDERDEVELOPED COUNTRIES
WITH REGARD TO THEIR ECONOMIC MEANS
AND MODERN TECHNOLOGY

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It's commonly believed that the semiconductor industry is synonym of a very advanced technology, which may be put profitably to work only in the more industrialised countries.

As a matter of fact, since 1948, the most important achievements in this field came from USA, although a lot of subsidiary techniques were developed in Europe, including specially the basic metallurgical principles on which the semiconductor industry rests.

However, the greatest majority of the actual devices have been developed in the States, with practically no exception, the most important ones being perhaps the post alloy diffused transistor, PADT, of Philips, Holand, and the tunnel diode due to Eisaki, Japan.

Since 1952, anyhow, demand for semiconductor devices has grown to such an extent that a mass production of highly sophisticated devices was requested. The "laboratory production" of the early fifties has been replaced by more repetitive technologies.

Only very special types are still produced under laboratory conditions on a small scale.

Advanced technologies are not, however, the single reason for the widely held opinion that the semiconductor industry does not fit the present needs of the less developed countries.

Lack of demand, the high import requirements and the unbalancing effect of a semiconductor industry not integrated within a well established electronic industry, provide further arguments for such a belief.

It is our opinion that establishing a semiconductor industry might be a fairly good investment of the scarce resources of at least some of the new emerging countries, and that therefore, planners and economists should not overlook it as they seem to do (1).

(1) An example is provided by the Third Five Year Plan of India where production of semiconductor is considered only as a "laboratory production" to be made by the Electronic Division of the Atomic Energy Commission.

The first factor on which we like to call the attention is the recent development of some basic technologies, substantially founded upon a more solid know-how (and in some cases upon what we could call "tricks") of processes that permit to avoid many of the big difficulties encountered in early years. The yield of production lines in terms of marketable units has increased to 70-90% as compared to 20-40 per cent around 1954.

Yet, the great number of highly repetitive elementary operations, necessary in the building-up of semiconductor devices, are well suited for a production through unexperienced manpower, who may acquire, in a very short time, all the ability and skill necessary.

In Italy young girls who never worked in a factory before, proved to be after a few months excellent labourers for the production lines of transistors. In the United States many semiconductor plants are located in rural areas of the South and make a large use of coloured unskilled workers.

We do not see why this should not be possible in some of the less developed countries.

Apart from unskilled manpower, the semiconductor industry requires a certain number of very well prepared technicians. Their number being proportional to the degree of sophistication of the devices produced and to the amount of original research that is carried out. If a plant for the production of 500 thousand high power silicon rectifier per annum might require 50 workers and 10 to 12 qualified scientists and engineers, a plant of the same size for entertainment transistor, might produce 4-5 million marketable units per years with the same amount of unskilled labor and 6 or 7 qualified technicians.

We do agree that the new emerging countries might be lacking a large amount of highly qualified technicians, but not the few that are required for low quality production. India, for instance, has quite a number of scientists working on atomic projects and so do other less developed nations.

As to original research, which is a must for industries working in a very competitive environment and for a very exacting market, it is not an absolute need for an industry working mostly for the entertainment market. Most of the semiconductor companies established in Europe have links with North-America companies, so do also many Japanese companies; the same pattern might be followed for establishing a semiconductor company in backward areas.

Cheap manpower has in the semiconductor industry a very important role because of the quick rate of obsolescence that the continuous improvements in the state of the art imposes upon fixed machinery.

Automatic operations require very sophisticated machinery and apparatus, the depreciation cost of which may be a substantial part of the cost of each unit.

For example, the cost of the equipment for an automatic line (PHILCO), requiring five skilled persons (1), for the production of about 1000 transistor per hour, is evaluated at 400.000\$: that means, considering a yield of 80% and a technological obsolescence of two years, 0.10 \$ per unit of depreciation cost, which might not be born if the selling price of transistors is in the range of fifty cents.

- (1) It has to be emphasized that in case of any failure in the automatic equipment, quite a number of highly specialized technicians are requested.

Another main characteristic of the semiconductor industry is the convenience of a low fixed investment also in the advanced countries because highly automatic lines of production need a large amount of capital and the time necessary for the complete design may render obsolete the device.

Moreover, the automatic production requires more elaborated parts to be fed into the line, which is another cause of increased costs.

We have shortly discussed the problem from a general view point; to give more strength to our argument we shall now try to give some estimates of hypothetical comparative costs.

Of course we are fully aware of the intrinsic weakness of the so called "engineering estimates" such as those we are using. Nevertheless it seems to us that they are sufficient to point out the right direction.

Let us consider two representative semiconductor devices, characterised by a well known technology, comparing the cost of the units in two different countries:

- 1) Italy (IT) where a manpower cost of 1 \$ per hour has been considered, and where some automatic operations are still convenient
- 2) Hypothetical Underdeveloped Country (HUC), where a manpower cost of 35 c per hour has been considered.

The devices taken into consideration are:

- a) low-power (200mW) general purpose Germanium alloy transistor (GeLP)
- b) power (3-20W) Germanium alloy transistor (GeLP)

a) GeLP - 2 millions good units per year
(considering a yield of 80%)

IT - Line investment, from wafer sorting and cutting to automatic final testing, including headers production.....140.000\$

HUC - Line investment, same consideration, with manual final testing 70.000\$

Cost of a marketable unit (cents)

	IT		HUC	
- Materials and parts	14,00	62,3%	11,00	63,1%
- Chemical, gases				
Denion. Water	1,00	4,4%	2,00	11,5%
- Manpower (30 workers + 2 foremen)	3,70	16,4%		
- Manpower (60 worker + 5 foremen)			2,50	14,4%
- Depreciation	3,50	15,5%	1,75	10,0%
- Interest on invest	0,28	1,2%	0,21	1,2%
TOTAL	22.48	100(a)	17.46	100(a)

(a) approximately

The cost per unit is calculated on the basis of the prices of the parts and apparatus as they are available in Italy. The rate of interest taken into account was 8% in Italy and 12% in the hypothetical underdeveloped country to consider the different availability of capital.

Depreciation was calculated - according to the prevailing standards of the industry - upon the basis of a two years obsolescence. It is however clear that in an underdeveloped country where technological progress is not so quick, depreciation might be spread over a much longer period. The more so if production is meant for the entertainment market.

We do not pretend to give here the absolute values, which may be, perhaps slightly lower, but to furnish a comparison between the two possibilities; the cost HUC is about 20% lower.

The difference between the two investments is mainly due to: 1) The cost of automatic test equipment which can be evaluated between 30,000 and 40,000 \$; 2) the cost of automatic machinery which is necessary with a relatively low number of workers. The last argument causes also a decrease for HUC, in the cost of direct materials and parts, which are less elaborated because of more manual operation.

We took into account a greater difficulty for HUC to get proper chemicals and, especially, good quality gases. The figure of 2 c per unit, in that case, depends largely from the conditions of the corresponding industry in each country.

It's possible, anyhow, to import large stocks of liquid gases of high purity.

So, the figure quoted should not be substantially incorrect.

b) GeHP - 500,000 good units per year
(considering a yield of 70%)

IT - Line investment, from wafer sorting and cutting to final testing (we do not consider here the automatic test equipment because yet considered from GeLP), including headers manufacturing 50,000 \$

HUC - Line investment, same conditions as above, plus 6,000 \$ of final test equipment, including headers manufacturing 56,000 \$

		Cost of a good unit (cents)			
		IT		HUC	
- Material and parts	22.4	49.0%		22.4	53.7%
- Chemicals, gases					
Deion. Water	3.0	6.5		6.0	14.4
- Manpower (30 Workers					
+ 2 foremen)	15.0	32.7			
- Manpower (30 Workers					
+ 3 foremen)				6.4	15.3
- Depreciation	5.0	10.9		6.0	14.4
- Interest	0.4	0.9		0.9	2.2
TOTAL	45.8	100%		41.7	100%

This represents a completely different situation, the difference in two cases being about 10%, in favour of HUC. This is only due to the manpower cost; the other costs are equal or higher, apart from the already mentioned considerations on depreciation.

The power transistor is the typical case for which, as far as we know, automatic productions are reduced to a minimum: the manpower is the greatest part of manufacturing cost.

As we mentioned before, we didn't take into consideration the cost of an automatic final test equipment because it was considered previously for GeLP.

We consider that such an apparatus could be used for both GeLP and GeHP at the same time.

We came practically at the same results as for GePH, with another typical device, a low cost medium current silicon rectifier (10-50 A / 50-300 PIV), which space limitations prevent us to expose here.

In fact the two cases presented here, GeLP and GeHP, are, in our opinion the two extreme possibilities between which we may classify, from the economical viewpoint, the greatest majority of the semiconductor devices actually produced, excluding the most advanced ones which are due, as we said previously, to a "laboratory production". For those devices the cost evaluation is particularly hard, and we shall not even try to provide our.

We didn't take into consideration, here, the investment for the general services because that is a function of the size of plant and of climatic conditions which cannot be generalised. Moreover, the possible higher cost of installation in HUC may be compensated by the lower cost of less automatic equipment and of maintenance.

Furthermore it's not unconceivable, in HUC, a manpower yield superior to that of other countries (a figure of 60-70% is quite common in USA), because of this possibility of a larger selection, thus contributing to lower the figures here quoted for that, in the case HUC. On the contrary, if instead of Italy we had chosen a more high salary representative of the industrialized countries, our estimates might have given even more favourable results for the underdeveloped country.

Engineering estimates show that achieving lower absolute costs of not too sophisticated semiconductor devices in an underdeveloped country than in a fairly industrialized one, is not absolutely out of the realm of possibilities. If this were true the establishment of a semiconductor industry might be advocated on the ground of its foreign exchange earning capabilities. We do know, however, that due to lower labour costs in underdeveloped countries estimates would provide similar results for many other industries.

Although one could also consider the case for an industry promoted by foreign capital and technicians for the sake of enjoying lower costs in order to export to industrialized countries, it is safer not to take into account such a possibility. It is our contention that a market for semiconductors exists also in the emerging countries.

Even in these countries there is in fact a quite considerable demand of lasting consumption goods so as transistor radioreceivers, which could be produced from domestic electronic industries. It could really be dangerous discriminating between the different types of demand, making use of choice principles which are not so easy to define. Moreover it is necessary to remember that the wide diffusion of low-costing radio-receivers may be an indispensable previous statement for a mass teaching program using radio and television which are with no doubt very effective means.

India, for instance, envisages to increase its production of radio-receivers from 254 thousand in 1960-61 to 800 thousand in 1965-66 (1). Unfortunately we do not give any breakdown as to traditional sets and transistorised sets. Nevertheless the market of radio-receivers is large enough to support a domestic production of semiconductors. Brasil in 1957 imported 16.27 million U.S. dollars worth of wireless apparatus of all kinds,

(1) See Government of India Commission Third Five Year Plan. p. 504.

reduced to 9.71 in 1960. We do not know how much of this amount is formed by radio-receivers. Yet the existence of a domestic semiconductor industry might help the establishment of a domestic production of radio-receivers.

Here comes the objections that the import requirements of the semiconductor are very high and that the establishment of such an industry is not in accordance with balanced growth.

As to the former consideration we must recognize that there is some truth in it. Both initial equipment and a large part of materials have not be imported. Nevertheless since the added value in the semiconductor industry is usually high, this factor assumes a relatively minor importance; in any case this problem has to be studied in each country according its balance of payment situation.

Concerning the semiconductor industry and balanced growth, apart from any frontal attack upon the whole concept of balanced growth (1), it might be easy to reserve the case and show that unless there is a domestic semiconductor industry it is pretty difficult to start an electronic industry.

It is necessary about this matter to remember that the increase of electronic industries must be accompanied by a well proportioned program for teaching and preparing good technical staffs at all levels. Electronic industries need in fact a number of skilled technicians who must be chosen between those who have good turn for the requested education type, and must be therefore trained with care. The preparing of a convenient number of technicians is hence necessary not only to the development of the electronic industry but also of all industries and services, because these activities use always more diffusely electronic means. This diffusion is in her turn a favourable element for the development of electronic industry's market.

It is our deep believe that nothing is more important in the use of modern electronic technologies than experience and that such an experience requires not to jump any step. The production of semiconductors is the first step to be made to enter the electronic industry. Since the electronic industry is acquiring in the industrialised countries a growing importance and might soon play a strategic role in the growth of an economy, there is no substantial reason why the new emerging countries should once more miss this challenging opportunity.

(1) See for this Albert O. Hirschman "The Strategy of Economic Development (New Haven 1958)